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Evaluating GAIA performances on eclipsing binaries.

III. Orbits and stellar parameters for UW LMi, V432 Aur and CN Lyn

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Abstract. The orbits and physical parameters of three detached F and G-type eclipsing binaries have been derived combining Hipparcos $H_{\rm P}$ photometry with 8480-8740 Å ground-based spectroscopy, simulating the photometric+spectroscopic observations that the GAIA mission will obtain. Tycho $B_{\rm T}$ and $V_{\rm T}$ light curves are too noisy to be modeled for the three targets, and only mean Tycho colors are retained to constrain the temperature. No previous combined photometric+spectroscopic solution exists in literature for any of the three targets. Quite remarkably, CN Lyn turned out to be an equal masses F5 triple system. Distances from the orbital solutions agree within the astrometric error with the Hipparcos parallaxes.

Key words. surveys:GAIA – stars:fundamental parameters – binaries:eclipsing – binaries:spectroscopic

1. Introduction

The Cornerstone mission GAIA, approved by ESA for launch between 2010 and 2012, will provide an astrometric, photometric and spectroscopic all-sky survey with completeness limits for astrometry and photometry set to $V = 20$ mag (about 1 billion stars) and to $V = 17.5$ mag for spectroscopy. The limits for meaningful epoch data will be proportionally brighter. The astrophysical and technical guidelines of the mission are described in the ESA's *Concept and Technology Study Report* (ESA SP-2000-4) and by Gilmore et al. (1998) and Perryman et al. (2001), and in the proceedings of recent conferences devoted to GAIA, edited by Straižys (1999), Bienaymé and Turon (2002), Vansevićius et al. (2002) and Munari (2003).

GAIA is expected to discover $\sim 4 \cdot 10^5$ eclipsing binaries, $\sim 1 \cdot 10^5$ of which should be double-lined spectroscopic binaries. This series of papers aims to (a) evaluate the GAIA performance on eclipsing binaries, to the aim of providing inputs for finer tuning of instrument focal plane assembly and data reduction pipeline, and (b) to determine reasonable orbital and stellar parameters for a number of double-lined eclipsing binaries unknown or poorly studied in literature. The strategy we adopted to simulate GAIA observations (both photometric and spectroscopic) is described in details in Papers I and II (Munari et al. 2001, Zwitter et al. 2003). We briefly recall here that Hipparcos/Tycho photometry is used as an approximation of GAIA photometry, while ground-based spectroscopic observations (obtained with the Asiago 1.82m + Echelle + CCD over the 8480-8740 Å GAIA range) are arranged to closely resemble GAIA spectral data.

Hipparcos scanning law and number of observations per object are pretty close to GAIA ones, the latter however observing in more photometric bands (∼10 compared to 3). The ∼10 GAIA bands (the exact number and characteristics are still subject to optimization, cf. Jordi et al. 2003) will however observe near-simultaneously during each of the ∼100 passages over a given star (cf. Katz 2003) during the 5 yr mission lifetime. Therefore, they will not augment the number of points defining the lightcurve, which will be mapped by the same ∼100 points as for Hipparcos. The accuracy of the photometric solution of an eclipsing binary rests less on the number of bands and more on the number of points mapping the eclipses as well as the other orbital phases. Thus the Hipparcos data, even if limited to only the H_P band, still well represent the GAIA potential to asses the stellar fundamental parameters from eclipsing binaries.

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Table 1. Program eclipsing binaries. Data from the Hipparcos and Tycho Catalogs. H_P is median value from Hipparcos, B_T and V_T are mean values from Tycho−II.

Name		Spct.	H_P	B_T	V_T	α_{J2000} (h m s)	δ_{J2000} (° ' ")	parallax (mas)	dist (pc)	μ^*_α (mas yr^{-1})	μ_δ (mas yr^{-1})
UW LMi	HIP 52465	G0	8.4528	9.025	8.386	10 43 30.20	+28 41 09.1	7.73±1.08	129^{114}_{150}	− 3.86±1.05	−98.58±0.72
V432 Aur	HIP 26434	G0	8.1377	8.700	8.110	05 37 32.51	+37 05 12.3	8.43±1.58	119^{100}_{146}	−39.18±1.08	+34.29±0.76
CN Lyn	HIP 39250	F5	9.1026	9.573	9.110	08 01 37.20	+38 44 58.4	2.76±1.53	362^{233}_{813}	− 4.43±1.91	+37.80±1.03

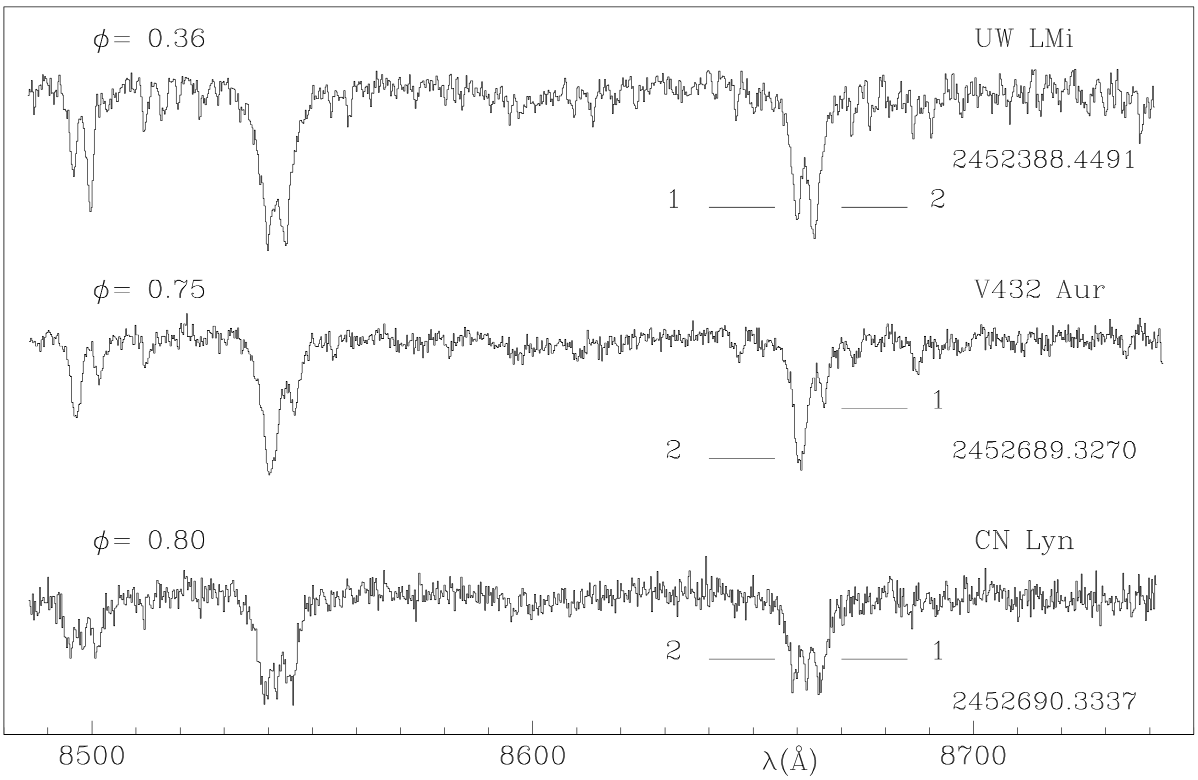

Fig. 1. An example of normalized Asiago spectra obtained at quadratures in the GAIA wavelength range is shown for each target star. The numbers indicate the components and the HJD identify the spectra in Table 3. In UW LMi spectrum the intensities of the Ca II lines are nearly equal in both components, while V432 Aur spectrum shows that the secondary star is more luminous. CN Lyn is a triple-lined system, with the central line associated to the third body.

In Paper I we selected three stars for which Tycho B_T and V_T light curves provided useful constraints, while for the three stars in Paper II their contribution to the analysis was marginal. With present Paper III we push a little bit more in this direction and consider three stars for which Tycho B_T and V_T light curves are useless in modeling the eclipsing binaries, the whole analysis resting on the H_P data alone. For the program stars of this paper, only Tycho $(B_T - V_T)$ mean colors are retained and used to constrain the temperatures.

The resolving power baselined for GAIA spectrograph is R=11 500 (Katz 2003), close to middle of the range 20 000 − 5 000 open for evaluation by ESA at the time this series of papers was initiated. Here we adopt a resolving power R=20 000, to balance a lower number of observations per star (typically 30-35 vs the 100 expected from GAIA) with a better resolution.

2. Target selection

For this third paper we selected three detached eclipsing binaries poorly studied in literature, all missing a proper combined photometric + spectroscopic solution. Their basic properties are reported in Table 1. For the first time we were faced with the problem of determining from spectroscopy both period and epoch of minimum, as one of

the target stars (V432 Aur) was a high amplitude variable unsolved by Hipparcos. Table 2 summarize the number of photometric and spectroscopic data available and their r.m.s. errors.

UW LMi. It is a well detached eclipsing binary discovered by Hipparcos ($P \sim 3.875$ days). It was classified as G0 V from objective prism spectra (Upgren & Staron 1970). Griffin (2001) obtained a spectroscopic solution, while Clausen et al. (2001) reported Stromgren *uvby* light curves, but did not derive a photometric solution.

V432 Aur. It was recognized as a large amplitude, unsolved variable star by Hipparcos ($H_{\rm P,min} - H_{\rm P,max} \sim 0.38$ mag), while its eclipsing binary nature was discovered by Dallaporta et al. (2002, hereafter D02), who derived a period of 3.08175 days. They also discovered intrinsic variability of the secondary star (maximum amplitude of $\Delta V \sim 0.05$ mag), which is not detectable in the less precise, less numerous Hipparcos data.

CN Lyn. It is a detached eclipsing binary discovered by Hipparcos ($P \sim 1.9554$ days). It was reported by Grenier et al. (1999) among the stars which show a discrepancy between the luminosity class given by visual classification and by Hipparcos parallax. Our GAIA-like spectra reveal the system to be triple, with nearly equal luminosity components (cf. Fig. 1).

3. GAIA-like radial velocities and Hipparcos photometry

The same set up as in the previous papers of this series is maintained here. The spectra were obtained with the Echelle+CCD spectrograph on the 1.82 m telescope operated by Osservatorio Astronomico di Padova atop Mt. Ekar (Asiago). The spectral range covered was $\lambda\lambda$ 8480−8740 Å, obtained in a single Echelle order without gaps. As mentioned in the previous papers the actual observations cover a wider wavelength region ($\lambda\lambda$ 4550-9600 Å), which will be exploited elsewhere together with ground-based, multi-band, dedicated photometry. The dispersion was 0.25 Å/pix which, with a slit width of 2.0 arcsec, leads to a resolution of 0.42 Å or equivalently to a resolving power of $R = 20\,000$.

The spectra were extracted and calibrated in a standard fashion using the IRAF software package running on a PC under Linux operating system. The high stability of the wavelength scale of the Asiago Echelle spectrograph has been discussed in Paper I.

The radial velocity measurements along with their Heliocentric Julian Date are given in Table 3. It is worth noticing that the smallest errors on the radial velocities are obtained for UW LMi which shows lines of equal intensity for both components. Larger errors affect V432 Aur where one component has spectral lines much weaker than the other, while the largest errors affect CN Lyn. The poorer S/N and the triple nature of the latter increase the blending and decrease the line contrast against the continuum, as the sample spectra displayed in Fig. 1 show.

Hipparcos epoch photometry was obtained from CDS. UW LMi and CN Lyn have reliable epoch photometry (they are classified as "class A" in the Hipparcos Catalogue), while V432 Aur has less reliable epoch photometry (class C). Details on the number of observations and their accuracy are given in Table 2.

Table 2. Number of Hipparcos (H_P) and Tycho (B_T, V_T) photometric data and ground based radial velocity observations, their mean S/N and standard error for the three program stars.

	Hip		*Tyc*			*RV*		
	N	$\sigma(H_P)$	N	$\sigma(B_T)$	$\sigma(V_T)$	N	S/N	$\sigma(RV)$
UW LMi	110	0.014	144	0.13	0.11	45	60	3.0
V432 Aur	49	0.010	59	0.10	0.12	43	67	5.0
CN Lyn	69	0.016	111	0.18	0.19	29	45	6.0

4. Modeling and Results

The modeling was performed with the Wilson-Devinney code (Wilson 1998) with modified stellar atmospheres (Milone et al. 1992) and with the newest limb darkening coefficients (Van Hamme and Wilson 2003). Interstellar reddening is taken to be negligible in accord with available extinction maps (Neckel & Klare 1980, Perry & Johnston 1982, Burstein & Heiles 1982).

Table 4 provides the derived system parameters along with their formal errors, while Table 5 compares the derived distances with the astrometric parallaxes from Hipparcos. Observational data and curves from the model solutions are shown in Figs. 2, 3 and 4.

For all the three objects, as quoted above and as can be seen from Figs. 2, 3 and 4, the Tycho photometric measurements are too scattered to be used in deriving a solution. In addition, given the detached nature of the target stars, the limited amount of points making up the $H_{\rm P}$ light curves do not properly cover both eclipses. Our solutions rely only on $H_{\rm P}$ light curves and radial velocity curves. The usual approach to binary star modeling is to use relative photometry obtained in each filter. The difference of eclipse depths gives the difference of stellar temperatures, while constraints on the absolute temperature scale can be obtained from simultaneous solutions in different filters (a different approach is outlined in Zwitter et al. 2003). The availability of a single light curve does not allow us to adjust the primary temperature (i.e. obtain the absolute temperature scale). We relied on median Tycho−2 colors and on their transformation to Johnson colors to derive it. The transformation between Tycho and Johnson systems is the same used in the previous papers, namely $V_{\rm J} = V_{\rm T} - 0.090 \times (B-V)_{\rm T}$, and $(B-V)_{\rm J} = 0.85 \times (B-V)_{\rm T}$ (from the Hipparcos Catalogue). The temperatures were not adjusted during the modeling. The temperature errors were evaluated to be $\sim$250 K. This could appear as an overestimate, but we think it is a fair approximation as it includes uncer-

Table 3. Journal of radial velocity data. The columns give the heliocentric JD at mid−exposure and the heliocentric radial velocities for both components (for the triple-lined system CN Lyn radial velocities refer to the components of the close binary).

UW LMi			V432 Aur			CN Lyn		
HJD	RV_1	RV_2	HJD	RV_1	RV_2	HJD	RV_1	RV_2
2451209.5638	−83.9	+1.9	2452302.4140	−83.5	+105.0	2451225.4627	+54.4	−87.0
2451210.5995	−108.6	+40.9	2452332.2787	+70.9	−45.2	2451229.4092	+60.4	−99.6
2451216.5219	+32.9	−97.5	2452358.3482	−69.7	+77.7	2451229.4365	+77.0	−98.5
2451217.4929	−97.5	+25.8	2452361.3665	−81.8	+88.4	2451274.4818	+81.9	−112.0
2451221.4874	−107.2	+35.5	2452361.3854	−70.1	+87.9	2451275.3214	−83.6	+51.9
2451225.4954	−112.8	+48.5	2452362.3392	+89.9	−59.3	2451507.5075	+72.3	−109.3
2451229.5905	−124.5	+52.6	2452504.5867	+104.6	−68.1	2451508.5187	−97.2	+64.6
2451229.6166	−111.2	+50.8	2452504.6057	+99.8	−71.2	2451589.5076	+88.2	−122.1
2451262.5398	+52.4	−121.1	2452505.5673	−47.9	+70.3	2451593.4673	+84.7	−115.3
2451262.5956	+49.5	−121.9	2452566.3983	+83.1	−59.3	2451594.4861	−120.2	+87.3
2451274.5101	+40.3	−107.9	2452566.4226	+77.7	−58.4	2451621.4071	−61.2	+48.8
2451279.4134	−89.0	+20.0	2452566.4466	+77.0	−51.4	2451625.4565	−109.6	+70.8
2451508.5690	−123.7	+46.9	2452566.4922	+74.9	−44.8	2451626.4652	+80.0	−112.8
2451564.5635	+42.3	−117.9	2452566.5153	+64.9	−36.8	2451894.4375	+96.6	−126.8
2451589.4661	−95.6	+29.6	2452566.5383	+58.6	−33.5	2451896.5461	+83.5	−122.1
2451594.4597	−69.4	+16.1	2452595.5037	−82.8	+93.2	2451924.4984	−65.5	+37.7
2451625.3834	−81.5	+17.0	2452598.3554	−91.1	+98.4	2451924.5828	−93.1	+42.8
2451626.4457	+42.1	−110.7	2452598.3825	−89.8	+97.4	2451983.4431	−126.8	+88.9
2451689.3282	+12.5	−82.1	2452598.4079	−89.9	+104.2	2452246.5590	+93.6	−135.0
2451690.3880	−107.3	+42.5	2452598.4336	−88.6	+96.3	2452272.6094	−71.0	+46.3
2451714.3348	−98.9	+31.9	2452598.4590	−78.8	+105.2	2452331.4401	−108.0	+90.4
2451714.3543	−95.0	+25.0	2452598.5042	−88.7	+86.0	2452331.4656	−119.7	+85.3
2451894.5996	+23.8	−86.2	2452598.5297	−79.1	+94.4	2452331.4886	−122.0	+92.7
2451895.5770	−101.2	+27.6	2452598.5551	−73.2	+98.4	2452332.4986	+88.0	−120.2
2451896.5134	−90.8	+18.7	2452627.4048	+90.9	−62.6	2452689.2516	−100.3	+73.5
2451896.6167	−81.2	+9.8	2452627.4305	+94.4	−67.4	2452689.2774	−112.7	+78.1
2451923.5948	−103.8	+25.8	2452627.4560	+96.3	−67.2	2452690.3081	+87.6	−112.6
2451924.5526	+23.2	−94.0	2452627.4831	+94.1	−71.4	2452690.3337	+89.6	−115.2
2451924.7333	+38.9	−116.6	2452627.5097	+100.3	−70.4	2452690.4403	+93.2	−116.0
2451983.5172	+37.5	−107.7	2452627.5352	+102.7	−72.8			
2451983.5446	+33.2	−110.7	2452627.6334	+107.2	−75.8			
2452242.6115	+38.7	−121.4	2452627.6596	+107.2	−76.8			
2452242.7379	+43.0	−131.3	2452627.6852	+103.6	−75.7			
2452272.5126	−68.5	+0.4	2452629.4800	−73.9	+91.3			
2452302.5234	−114.7	+55.7	2452629.5060	−56.6	+89.5			
2452330.5314	−86.9	+3.6	2452629.5523	−64.7	+78.9			
2452330.5571	−81.9	+7.7	2452689.3010	+103.6	−78.7			
2452358.5207	+29.3	−99.2	2452689.3270	+105.9	−78.1			
2452359.4484	+30.6	−97.1	2452689.4683	+98.5	−75.5			
2452362.3746	+32.0	−94.0	2452689.4942	+96.2	−75.6			
2452387.4354	−82.5	+18.2	2452690.3589	−41.5	+63.0			
2452388.3798	−109.6	+36.3	2452690.4646	−64.4	+71.2			
2452388.4491	−99.3	+33.2	2452690.4904	−67.2	+74.5			
2452389.3627	+16.7	−87.9						
2452389.3876	+18.4	−87.4						

tainties in B_T and V_T measurements, their transformation to Johnson system, color calibration of spectral types and effective temperature calibrations of spectral types. Uncertainties in the adopted temperatures and the poorness of phase coverage of the light curve reflect mainly on the derived radii and luminosities and thus distances of the target stars.

None of the target stars shows the signature of an eccentric orbit. The circularity of the orbits was confirmed by initial modeling runs during which eccentricity was allowed to vary and remained consistent with zero. After a few of such trials e was set to zero.

Table 4. Modeling solutions. The uncertainties are formal mean standard errors to the solution. The last two rows give the r.m.s of the observed points from the derived orbital solution. †: the error on the temperature is not reported because it was not adjusted in the modeling, it was estimated to be ∼250; ‡: the error on the temperature of the secondary component is not reported because even if it was adjusted in the modeling, it depends on the primary temperature, it was evaluated to be ∼260.

parameter (units)	UW LMi	V432 Aur	CN Lyn
Period (days)	3.874309±0.000004	3.081745±0.000004	1.955507±0.000002
Epoch (HJD)	2450205.822±0.002	2447864.069±0.003	2448500.251±0.001
a ($R_\odot$)	13.27±0.06	11.29±0.06	8.40±0.05
V_γ (km sec^{-1})	−35.2±0.3	+10.5±0.4	−15.6±0.5
$q = \frac{m_2}{m_1}$	0.982±0.009	1.09±0.01	1.00±0.01
i (deg)	86.7±0.1	87.0±1.5	89.7±0.5
e	0.0	0.0	0.0
T_1 (K)	6500†	6100†	6500†
T_2 (K)	6500†	5900†	6455‡
Ω_1	11.8±0.4	9.2±0.5	5.7±0.5
Ω_2	11.8±0.5	6.8±0.4	5.6±0.6
$\Re_1$ ($R_\odot$)	1.23±0.05	1.39±0.08	1.80±0.21
$\Re_2$ ($R_\odot$)	1.21±0.06	2.13±0.14	1.84±0.24
M_1 ($M_\odot$)	1.06±0.02	0.98±0.02	1.04±0.02
M_2 ($M_\odot$)	1.04±0.02	1.06±0.02	1.04±0.02
$M_{bol,1}$	3.83±0.19	3.76±0.22	2.99±0.30
$M_{bol,2}$	3.86±0.20	2.98±0.23	2.99±0.28
log g_1 (cgs)	4.28±0.03	4.14±0.05	3.94±0.10
log g_2 (cgs)	4.29±0.04	3.81±0.06	3.93±0.11
$\sigma_{RV,1,2}$ (km sec^{-1})	8.2,6.7	8.6,6.0	5.4,9.0
σ_{H_P} (mag)	0.029	0.024	0.033

4.1. UW LMi

For UW LMi it has been necessary to adjust epoch and period and make the photometric and spectroscopic ephemerids agree, because original Hipparcos ephemeris was not working. The primary star as defined by Hipparcos is our more massive star so we decided to retain it as primary, even if both Griffin (2001) and Clausen et al. (2001) adopted the reverse convention. The strategy to obtain the primary temperature was described above. Tycho−2 data provide $(B-V)_\mathrm{T} = 0.625$, which, transformed to the Johnson system, leads to $(B-V)_\mathrm{J} = 0.53$. An inspection of the spectra and of the radial velocity curve tells us the two stars are not much different. Supposing both stars have equal temperatures, the color suggests (according to Fitzgerald 1970 and Popper 1980 conversion tables) that they are somewhat hotter (F8) than the reported G0 spectral type. The secondary eclipse is not well mapped in Hipparcos data and this prevented us from adjusting even the temperature difference. Using the calibrations from Straižys & Kuriliene (1981), an F8 spectral type implies an effective temperature of 6150 K, while a G0 type gives $T_\mathrm{eff} = 5950$ K. The spectrum in Fig. 1 however shows an appreciable Paschen 14 line which intensity relative to the CaII triplet supports a somewhat higher 6500 K temperature (cf. synthetic spectral atlas of Munari and Castelli 2000). We thus tried four different model solutions:

(*a*) $T_{\mathrm{eff},1} = T_{\mathrm{eff},2} = 6500$ K,
(*b*) $T_{\mathrm{eff},1} = T_{\mathrm{eff},2} = 6150$ K,
(*c*) $T_{\mathrm{eff},1} = 6150$ K and $T_{\mathrm{eff},2} = 5950$ K
(*d*) $T_{\mathrm{eff},1} = T_{\mathrm{eff},2} = 5950$ K.

Table 5. Comparison between the Hipparcos distances and those derived from the parameters of the modeling solution in Table 4.

	Hipparcos (pc)	this paper (pc)
UW LMi	129^{114}_{150}	114±7
V432 Aur	119^{100}_{146}	124±10
CN Lyn	362^{233}_{813}	285±32

Model a gave a better convergence and thus $T_{\rm eff} = 6500$ was adopted for both stars. The relative intensity of Paschen 14 and CaII lines in the spectrum of Fig. 1 strongly support such a temperature when compared with the synthetic spectral atlas of Munari and Castelli (2000). The derived masses and radii ($M_1 = 1.06\ M_\odot$, $M_2 = 1.04\ M_\odot$, $R_1 = 1.23\ R_\odot$, $R_2 = 1.21\ R_\odot$) are consistent with those of nearly equal stars slightly hotter and heavier than the Sun and still within the main sequence band even if slightly away from the ZAMS locus. Griffin (2001) suggested that both components of the system are more luminous than MS stars. The derived mass ratio ($q = 0.982 \pm 0.009$) is completely consistent with that obtained by Griffin (2001) whose $q = 1.017$ transforms to $q = 0.983$ when stars are labeled according to our scheme.

4.2. V432 Aur

V432 Aur revealed itself as the most challenging of the targets. As quoted above, D02 derived precise a period and epoch of minimum for V432 Aur. With the aim to rely on Hipparcos photometry and GAIA-like radial velocities only, we neglected the D02 results and recovered the ephemeris from these data alone. We were able to obtain initial values for period and epoch from spectroscopy, using a Deeming-Fourier analysis that provided a clean and fast detection of the orbital period as shown in Fig. 5. Successively, we refined the ephemeris combining spectroscopic observations with Hipparcos H_P photometry. The secondary eclipse is virtually not mapped by Hipparcos (cf. Fig. 3), so it is highly uncertain to determine which star is the primary and to constrain the temperature difference. As GAIA will obtain photometry in 11 photometric bands, and its spectra will be analyzed with synthetic spectral techniques, such uncertainty will not be typical of GAIA observations of an eclipsing system like V432 Aur, and we thus accepted to insert just one external information, from D02, e.g. the color difference between the two eclipses. Tycho−2 color $(B-V)_{\rm T} = 0.590$ transforms to $(B-V)_{\rm J} = 0.50$ which, supposing both stars have equal temperatures, supports an F7−F8 spectral type, somewhat hotter than the G0 type listed in SIMBAD. The primary star is our less massive star and using $\Delta(B-V)_{\rm J} = 0.05$ mag at primary eclipse from D02 we obtain $\Delta T_{\rm eff} \sim 200-500$ K. Again we tried different models with $6000\ {\rm K} \le T_{\rm eff,1} \le 6300$ K, exploring the range $200 \le T_{\rm eff,1} - T_{\rm eff,2} \le 500$ K. The final adopted temperatures are $T_{\rm eff,1} = 6100$ and $T_{\rm eff,2} = 5900$, corresponding to F8 and G0 spectral types (Straižys & Kuriliene 1981), in agreement with appearance of the spectrum in Fig. 1. The spectra helped us to have an initial value for the luminosity of the stars. An inspection of them reveals that the hotter and less massive primary star is the less luminous, because the difference in the Ca II lines intensities cannot be ascribed to the small temperature difference (cf. the GAIA spectral atlases by Munari & Tomasella 1999, and Munari & Castelli 2000). The adopted temperatures together with the derived masses and radii ($M_1 = 0.98\ M_\odot$, $M_2 = 1.06\ M_\odot$, $R_1 = 1.39\ R_\odot$, $R_2 = 2.13\ R_\odot$) imply that the secondary component is more massive, more luminous and cooler than the primary, suggesting it has evolved farther away from the MS than the primary component.

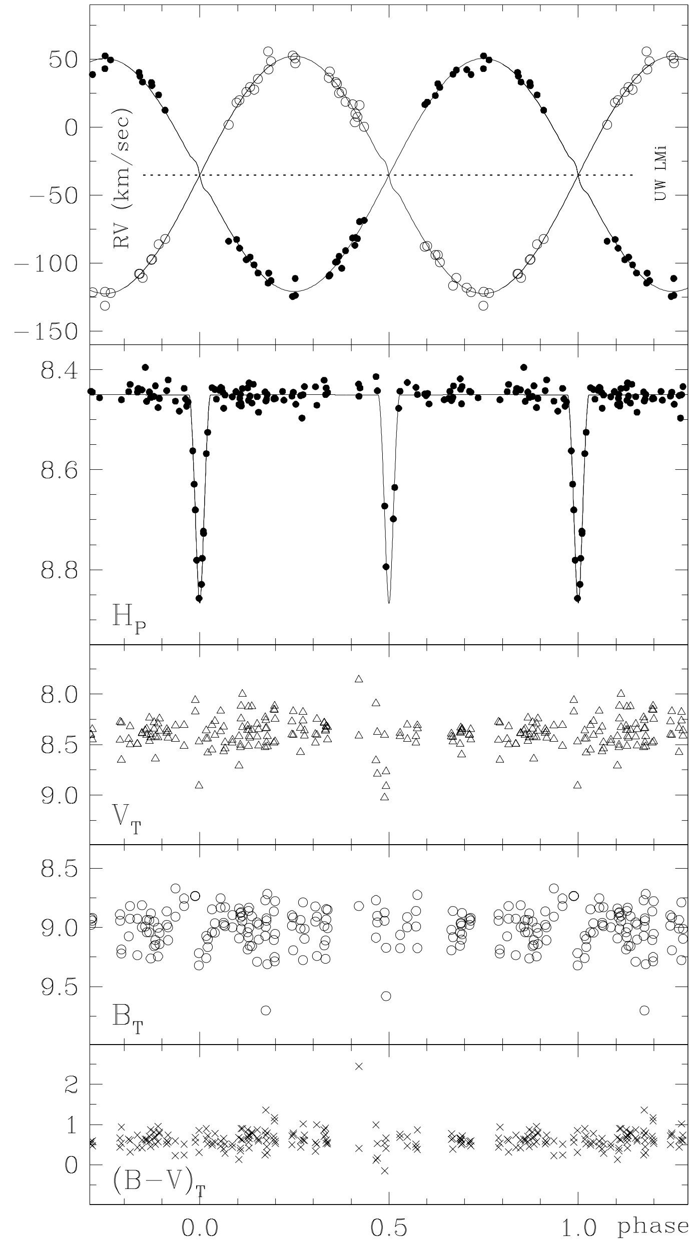

Fig. 2. Radial velocity curves (measurements are from Table 3, obtained in the GAIA spectral region) and Hipparcos H_P and Tycho $V_T, B_T, (B-V)_T$ light curves of UW LMi folded onto the period $P = 3.874309$ days. V_T and B_T are shown for illustration purposes and were not used for modeling. The lines represent the solution given in Table 4, with proximity effects (appropriate if the corotation hypothesis holds) taken into account.

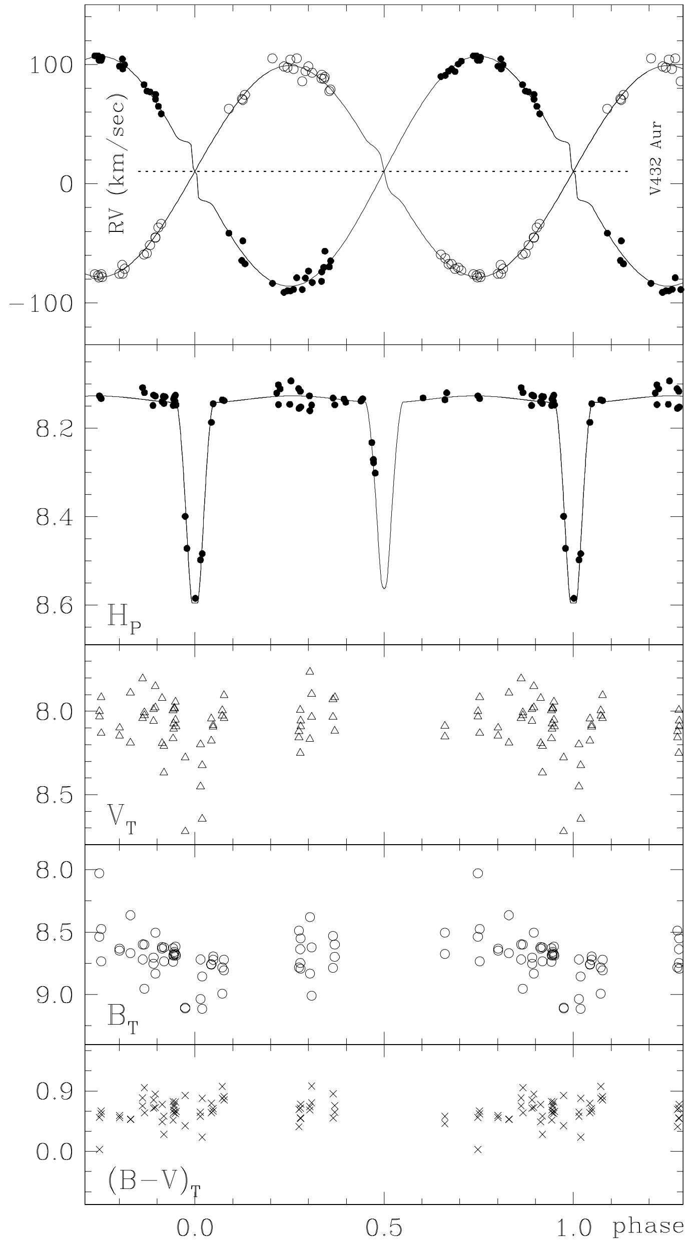

Fig. 3. Radial velocity curves (measurements are from Table 3, obtained in the GAIA spectral region) and Hipparcos H_P and Tycho $V_T, B_T, (B-V)_T$ light curves of V432 Aur folded onto the period $P = 3.081745$ days. V_T and B_T are shown for illustration purposes and were not used for modeling. The lines represent the solution given in Table 4, with proximity effects (appropriate if the corotation hypothesis holds) taken into account.

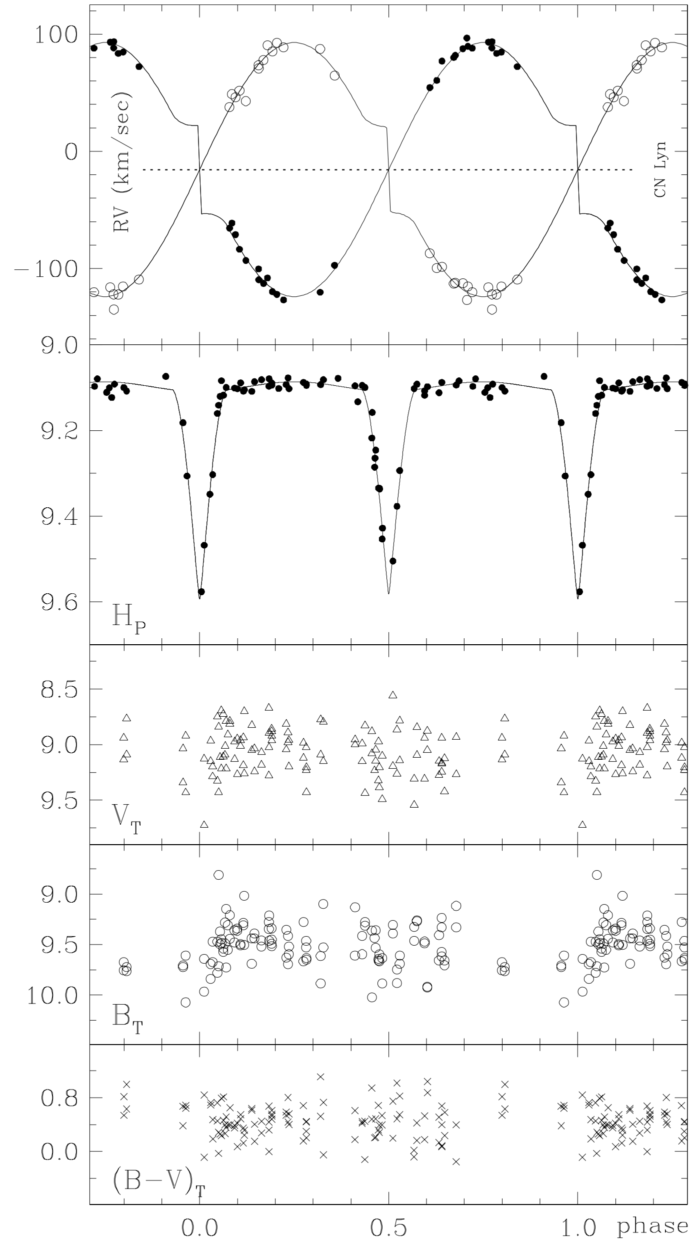

Fig. 4. Radial velocity curves (measurements are from Table 3, obtained in the GAIA spectral region) and Hipparcos H_P and Tycho $V_T, B_T, (B-V)_T$ light curves of CN Lyn folded onto the period $P = 1.955507$ days. V_T and B_T are shown for illustration purposes and were not used for modeling. The lines represent the solution given in Table 4, with proximity effects (appropriate if the corotation hypothesis holds) taken into account.

4.3. CN Lyn

This triple system is the most intriguing of the three program stars. Its GAIA-like spectra show that the three components are quite similar in temperature, gravity and luminosity (cf. Fig. 1). Tycho-2 photometry $(B-V)_{\rm T} = 0.463$ transforms to $(B-V)_{\rm J} = 0.39$ and, supposing all three components have equal temperatures, it suggests F3−F4 spectral types, in good agreement with the F4−F5 type reported in SIMBAD and the spectral appearance in Fig. 1. The adopted $T_{\rm eff,1}$ was 6500 K. Eclipses are quite well mapped by $H_{\rm P}$ photometry and the secondary temperature was thus adjusted. The contribution of the third body to the light curve was taken into account by adding a constant third light, $l_3 = 29(\pm 6)\%$ of the total flux. The derived temperatures ($T_{\rm eff,1} = 6500$ K, $T_{\rm eff,2} = 6455$ K), masses ($M_1 = M_2 = 1.04\ M_\odot$) and radii ($R_1 = 1.80\ R_\odot$, $R_2 = 1.84\ R_\odot$) show that the components of the close

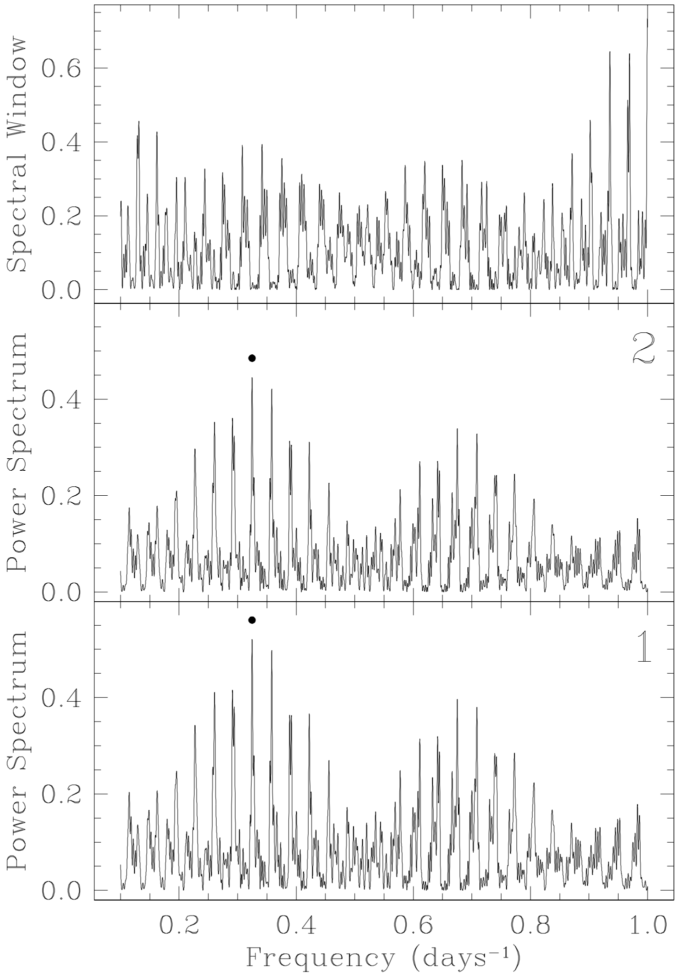

Fig. 5. Results of the Deeming-Fourier period search on the radial velocities of both V432 Aur components from Table 3. The abscissas span the 1-10 days interval and the dots mark the peak corresponding to the period in Table 4. Side peaks are the lunation aliases, while much weaker year aliases contributes to the background *noise*. The second group of peaks centered at frequency 0.65 corresponds to half of the true period.

binary are virtually identical (within the quoted formal errors) and marginally evolved away from the MS.

The third body mean radial velocity (-13 ± 1 km/sec) is consistent with the systemic velocity of the close pair ($V_\gamma = -15.6 \pm 0.5$ km/sec). A period search has failed to reveal a clear periodicity in the radial velocities of the third body, which limited range of radial velocities displayed in our spectra (21 km/sec) can be caused by an orbital period much longer than the time spanned by our observations (3.2 yr) and/or a low orbital inclination.

5. Conclusions

The three targets were chosen without restrictions on peculiarities or variability and faint enough so that Tycho 2 photometry is useful only in providing mean colors and not epoch data. Only H_P data were therefore available to map the lightcurve, which compromised the accuracy of derived effective temperatures of the components (both the absolute scale and the difference).

Even under such limitations (aiming to simulate GAIA observations of targets more difficult that those explored in Paper I and II of this series) reasonable solutions have been achieved for all the three targets, with the distance implied by the orbital modeling within the uncertainty bar of the Hipparcos parallax for all the three stars, including the equal masses triple system. This reassuring external and independent check reinforces the expectation of a high impact of GAIA observations for the derivation of fundamental stellar properties from observations of eclipsing binaries, and the direct use of GAIA observations of eclipsing binaries as a valuable measure of distances in itself.

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